
THE INTERPRETATION OF ERS-1 AND ERS-2 INSAR DATA FOR THE MINING SUBSIDENCE MONITORING IN UPPER SILESIAN COAL BASIN, POLAND

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ABSTRACT

The successful application of the SAR Interferometry (InSAR) for interpretation of land subsidence, especially in coal mining areas is described in this paper. The set of interferograms was collected in Poland over Upper Silesian Coal Basin, where subsidence causes damages to buildings and changes of surface drainage patterns in a densely urbanized area. InSAR is a technique, which uses the phase difference between the radar echoes from repeated SAR (Synthetic Aperture Radar) images of the same area. InSAR is now a unique method, which gives us possibility to take a measurement of land subsidence on a strict determined huge area of tenths thousand square kilometers and a precision state in time range. Interferometric image of land subsidence over the SAR observation period of 35 and 70 days shows the subsidence increment on advancing slope of subsidence through. Elliptic-shape area of the presence of subsidence is high correlated with the extent of the front of underground mining. It allows interpreting also non-technological subsidence factors. The factors presented in this paper there are: lithology of cap rocks, dip of the coal bank, presence of abandoned workings. The high valuable InSAR data can become in future the basic, independent source of information about surface dynamics in Upper Silesian Region.

1 INTRODUCTION

In densely urbanized area of the Upper Silesia the subsidence due to underground coal mining affects an area of 600 km² each month and results deformations of the ground, and damages to buildings, roads and railways. The test of applicability of ERS SAR interferometry (InSAR) for the subsidence detection in this area shows a high potential of the interferometry (Perski 1998). Now, this work is continued in AO3-127, a project of ESA 3rd announcement of opportunity for exploitation of ERS data and aims to provide long-time monitoring of surface changes in the Upper Silesian Coal Basin. In this project the results of ERS SAR interferometry are interpreted in conjunction with conventional sources of the information about the subsidence, mining activity and geology.

2 METHOD OF THE STUDY AND ERS SAR DATA SELECTION

SAR interferometry is a technique to extract the high accurate information about vertical height changes of the Earth surface using the phase difference between the radar echoes from repeated SAR observations of the same area. SAR interferometry has demonstrated a high potential in measuring natural and man-induced surface movement (Massonnet, Feigl 1998, Stow et al. 1999, Strozzi et al. 1999). Repeated ERS-1 and ERS-2 SAR observations of the selected test sites in the Upper Silesia (Fig.1) have been used to process interferograms which present a pattern of elliptical fringes - the indicators of the phase shift of radar signals caused by the mining subsidence (Perski, Jura 1999).

Despite the all-weather capability of space-born radar, the data availability in the case of the SAR interferometry is strongly reduced by strict requirements with respect to orbital parameters, climatic season and daily weather conditions (Tarayre, Massonnet 1994). One of the most important tasks in case of subsidence detection is the selection of best-suited couples of SAR images, in order to minimize the influence of possible errors and to convince the observed fringe patterns will represent only surface changes - i.e. the effect of mining subsidence.

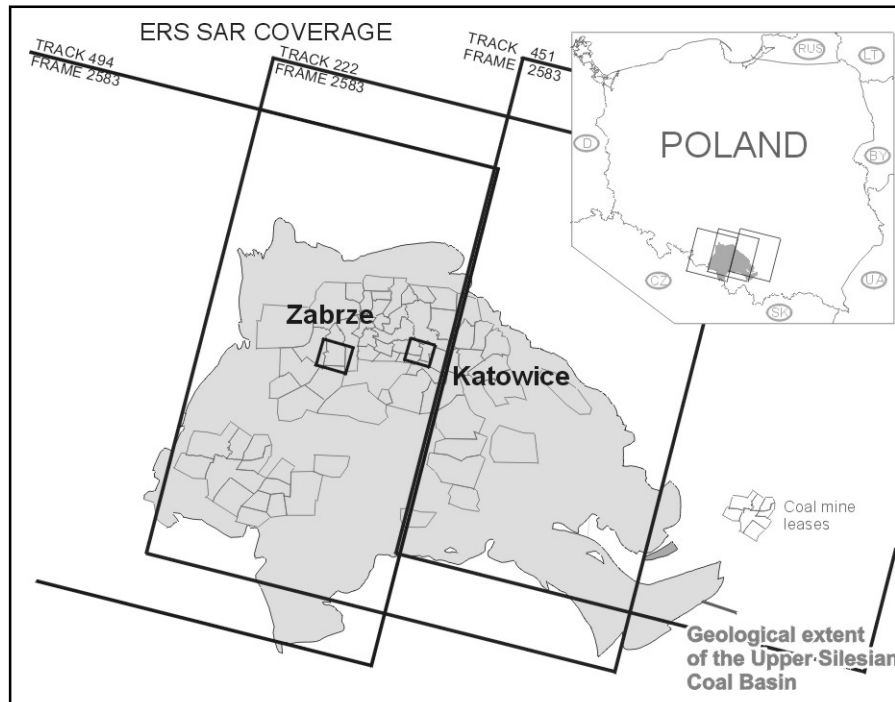


Figure 1. Location map of the study area with ERS SAR coverage

In the AO-3 127 project the couples of ERS SAR data acquired from very close orbits, with perpendicular baselines not exceeding 100 m have been selected (Perski 1998, Perski, Jura 1999). Such selection practically eliminates the effects of the topographic influence, since the height resolution becomes very coarse. These carefully selected pairs have been further selected according to weather and season condition on the day of acquisition (Perski 1999). In the second phase of this project the selection of SAR images for InSAR processing have been carried out according to larger baselines and longer time-bases despite different seasons and variable weather. The different criteria of selection have been applied to establish the real extents of capability of InSAR method.

In the presented work, the methods of two-pass interferometry (Pratti et al. 1996) and four-pass interferometry (Atlantis 1997) have been applied for generation of interferograms. The topographic phase removal have been carried out using the interferometrically processed DEM from ERS tandem data. The final DEM was obtained based on two InSAR DEMs processed from ascending and descending tandem ERS SAR data. The correction of coordinates and height values of DEM have been performed based on GCP points digitized from topographic map scale 1:10 000. In the future, the correction will be done also based on GPS measurements. The resulted interferograms have then been analyzed together with digital maps of mining activity and geological maps, and with the database of geodetic and GPS measurements. For integration and analysis of different data the GIS system ILWIS 2.2 have been used.

3 THE INTERPRETATION OF INTERFEROGRAMS

The interpretation of interferometric data shows that the pattern of the interferometric fringes represents the increment of subsidence within a period between two data acquisitions - in practice 35 and 70 days. The centre of the fringe - an area of maximum surface downwarp - is located exactly in the middle of the active (advancing) slope of the extending subsidence trough and thus indicates the zone of the highest rate of surface changes (Jura, Perski 1999). The comparison between the location of the fringe and the position of underground exploitation front allows us to evaluate the rate of retardation in subsidence phenomena and its dependence on the mining technology. The results of accurate measurements of the rate of subsidence and the location of the fringes performed on interferograms allow calculating the increment of inclination and the velocity of subsidence. On the basis of the geological interpretation of ERS SAR interferograms, in conjunction with the mining and geological maps, the dependence of the velocity of subsidence on the structure of the cap rock and dip of the strata can also be determined.

In the test area in Katowice city (Figs. 1 and 2) the comparison of the retardation distance measured between position of mining front and the centre of interferometric fringes with the adjacent rate of mining advance shows that the influence of mining was observed on the surface already after 3 to 4 months. Such a short time of impact can be explained by the relatively shallow exploitation, the presence of 50-m-thick Quaternary deposits in the Rava river valley and already existing damages of overlying rocks caused by old abandoned workings. In the presented interferograms of Muchowiec Airport in Katowice the observed fringe pattern shows in 1993 very clear asymmetry in northeasterly direction. This part of interferogram represents an effect of residual subsidence caused by works abandoned in 1991 and 1992. The rate of monthly subsidence in presented period was here 2 to 0.5 cm per 35 days.

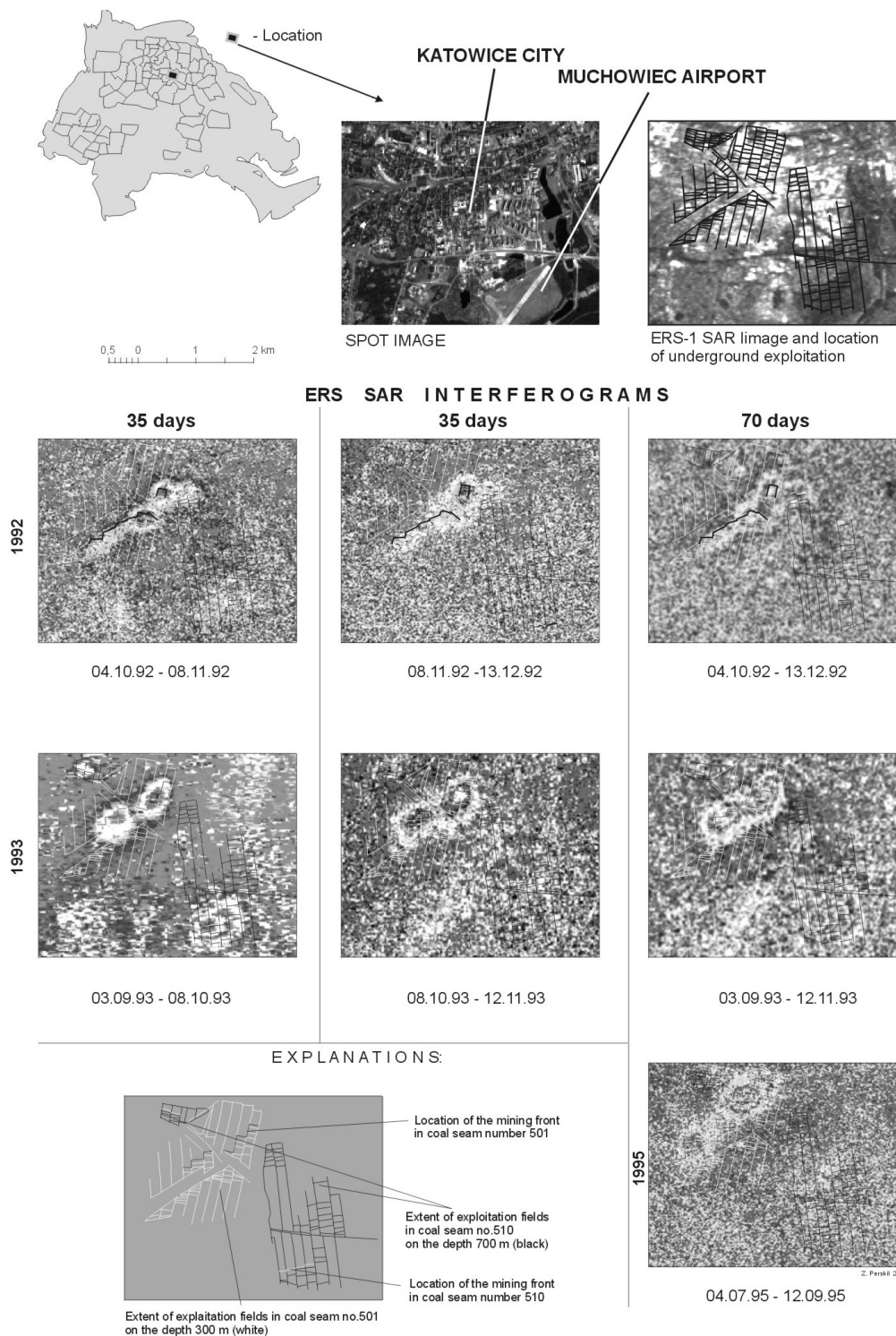


Figure 2. Katowice area InSAR images with associated underground coal exploitation

In Zabrze area the shift between center of the interferometric fringe and the position of mining front was diagonal to the direction of mining forward. The GIS comparison with structural maps of mined coal seams shows that the shift strongly relates to the dip of the strata (Fig. 3). The observed on interferograms the influences of dip of the coal seams on the surface subsidence have been similar to „deviation of mining influences” a common subsidence phenomenon (Borecki 1980, Kwiatek 1997). Interferometric data presents the summarized effect of deviation and shift caused by mining forward for short time interval.

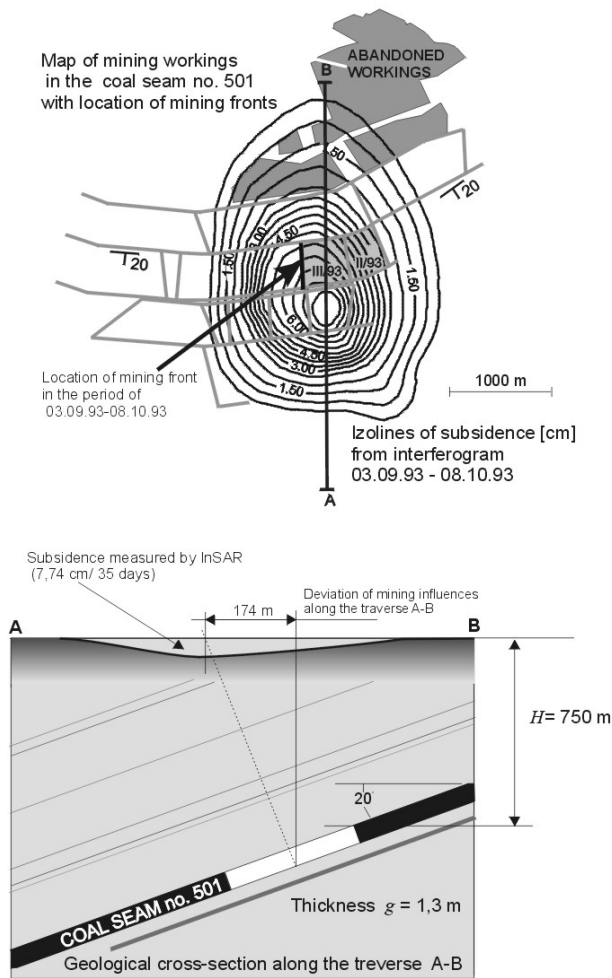


Figure 3. The deviation of mining subsidence caused by impact of dip of the strata

4 CONCLUSIONS

This study shows that application of SAR interferometry for mining subsidence studies opens a new application research, in particular for subsidence dynamics and their spatial distribution. For the first time interferograms of the Upper Silesia present the scale of the real terrain deformations for the whole area in rather small time intervals. Interferometric near real-time data are very important in the Upper Silesia especially for urban planning and protection of linear constructions as roads, railways and pipelines.

Analysis of interferograms shows that the fringe pattern strongly relates on the position, shape and length of the mining front, the rate of mining advance and technique applied for the roof control and the geological structure of rock mass and the presence of abandoned underground workings.

Interferometric measurements of subsidence over a large area appear to be more realistic than traditional surveys, especially because the fast surface displacement, persisting for 2 to 3 months only.

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